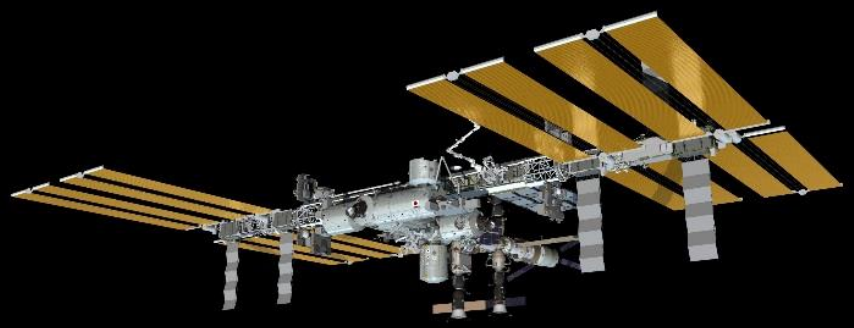


TEXTILES FOR LIVING IN SPACE

International Space Station (ISS) and Beyond

Henry Tang, NASA Johnson Space Center / Aerodyne Industries

IFAI EXPO 2017, New Orleans, LA, USA

IFAI EXPO

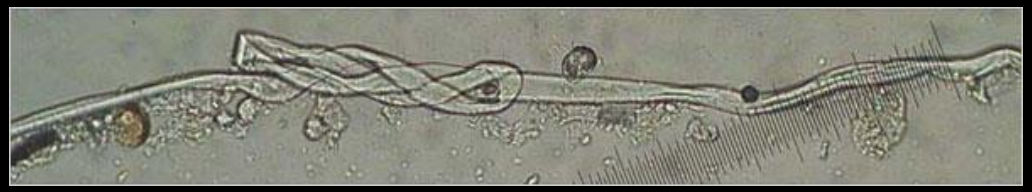
NASA

TEXTILES AND SPACE EXPLORATION

- Why use textiles for spaceflight?
- What type of spaceflight?
- How to select these textiles?

TEXTILES FOR SPACE EXPLORATION

- Human and textiles
  - Textiles are one of the oldest engineering material



- Unique engineering properties
  - Lightweight
  - Flexibility (minimize volume)
  - High strength to weight ratio
  - Composite structure

TEXTILES FOR SPACE EXPLORATION

Two Environmental Categories

Intravehicular Activity (IVA) – Inside spacecraft environment

Extravehicular Activity (EVA) – Outside spacecraft or planetary environment

TEXTILES APPLICATIONS

- Extravehicular Activity (EVA)
  - Thermal insulation blanket and cover
  - EVA tools – tether, restraint, etc
  - Spacesuit fabric layup
  - Inflatable structure
  - Composite material structure
- Intravehicular Activity (IVA)
  - Crew clothing
  - Acoustic insulation
  - Bag and storage containers
  - Sleep station cover, cushion
  - Exercise aids

SPACE / SPACECRAFT ENVIRONMENTS

- Atomic Oxygen (AO) - LEO
- Micro Meteor Orbital Debris (MMOD) -LEO
- Thermal Extreme – LEO (± 250 F)
- Space Vacuum – LEO, Moon, Mars
- Radiation (UV, Ionizing Protons & Electrons, Galactic Cosmic Rays) – LEO, Moon, Mars
- Solar Energetic Particles – LEO, Moon, Mars
- Closed System Environment – close loop life support system compatibility - Spacecraft
- Unique planetary conditions – Moon, Mars

UNIQUE CHALLENGES

- Desirable properties for various spaceflight applications
  - Nonflammable - IVA
  - Low toxicity - IVA
  - Thermal vacuum stable - EVA
  - Dust Resistance - EVA (planetary)

IVA CHALLENGES - FLAMMABILITY

- Flammable material creates fire and safety hazard
- Nonflammable in enrich oxygen spacecraft environment required
- Pass NASA flammability test (NASA-STD- 6001, Test 1) required
  - Bottom ignition upward flame propagation test
  - Burn length < 6”
  - No transfer of burning debris (melt and drip)
- Limit fabric choice for clothing and IVA applications

Flammability of common textile fibers in various oxygen environments

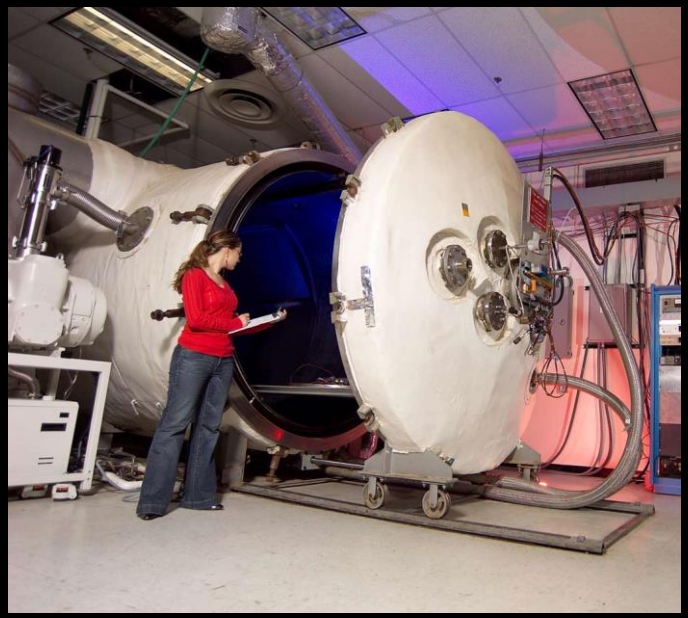
Textile Fibers	Earth 21 % O_2	ISS Airlock / Cabin 30 % O_2	Future Spacecraft > 34 % O_2
Cotton (LOI ~19%)	×	×	×
Polyester (LOI ~ 22%)	×	×	×
Wool (LOI ~ 22%)	✓	×	×
Modacrylic (LOI ~ 26%)	✓	×	×
Nomex (LOI ~ 31%)	✓	✓	×
P84 (LOI ~ 33%)	✓	✓	×
FR Cotton (LOI ~ 34%)	✓	✓	×
Durette (LOI ~ 38%)	✓	✓	✓
PBI (LOI ~ 38%)	✓	✓	✓
Carbon (LOI > 55%)	✓	✓	✓
Teflon (LOI > 95%)	✓	✓	✓
Fiberglass (LOI ~ 100%)	✓	✓	✓

IVA CHALLENGES - TOXICITY

- Close loop system promotes accumulation of offgassed products that could creates safety hazard
- Low toxicity outgassing required
- Pass NASA toxicity test (NASA-STD-6001, Test 7 or ISO-14624-3)
  - Tested for 72 hours at 122 F
  - Established spacecraft maximum allowable concentrations (SMACs) for contaminants per JSC 20584
  - Toxicity hazard index < 0.5
- May limit the use of coating or textile surface treatment (e.g. FR treatment)

EVA CHALLENGES – THERMAL VACUUM STABILITY

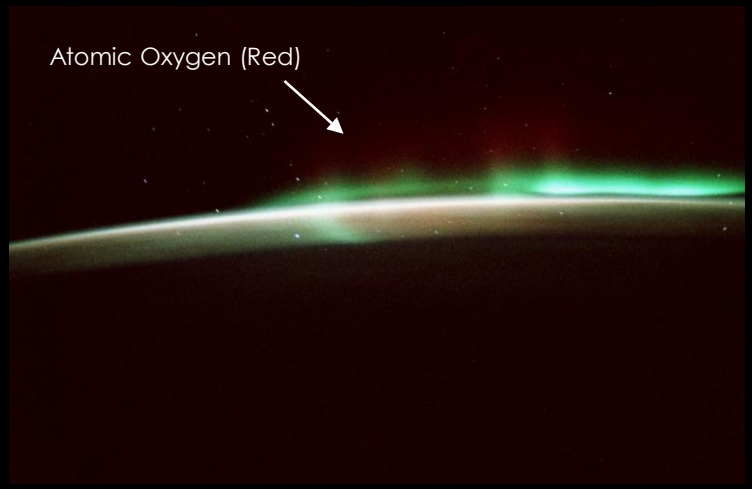
- Textile material outgassing in thermal vacuum environment
- Outgas product such as volatile condense materials (VCM) can contaminates critical space hardware
  - Thermal radiation surfaces
  - Solar panel surfaces
- Pass NASA TVS test (JSC SP-R-0022A and/or ASTM E595)
  - Total mass loss ≤ 1.0 %
  - Total VCM ≤ 0.1 %



EVA CHALLENGES – ATOMIC OXYGEN

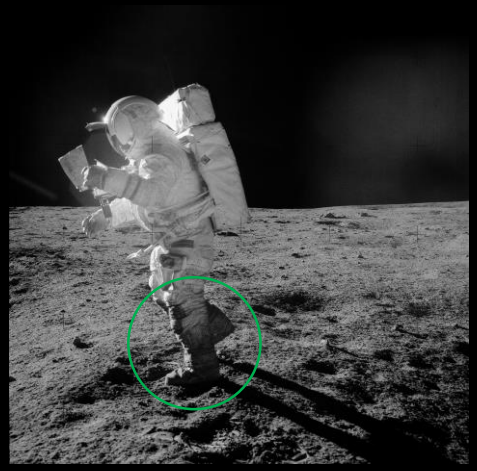
- Atomic Oxygen (AO) is an element in the low earth orbit (LEO) environment that degrades certain structural materials
- LEO comprised of 96% AO
- Degradation of materials by oxidation and erosion
- Alter texture, hydrophilicity of material surface properties

Sources of Oxygen + UV → O
(Atomic Oxygen)



EVA CHALLENGES - DUST

- Lunar / Mars dust issues
  - Contamination and abrasion of spacesuit materials
  - Contamination of critical EVA hardware surface
  - Contamination of IVA crew cabin and equipment

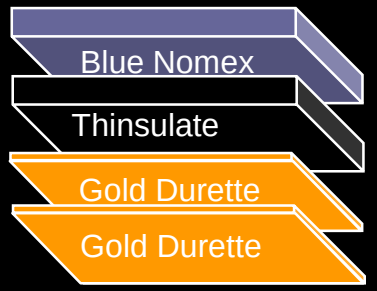


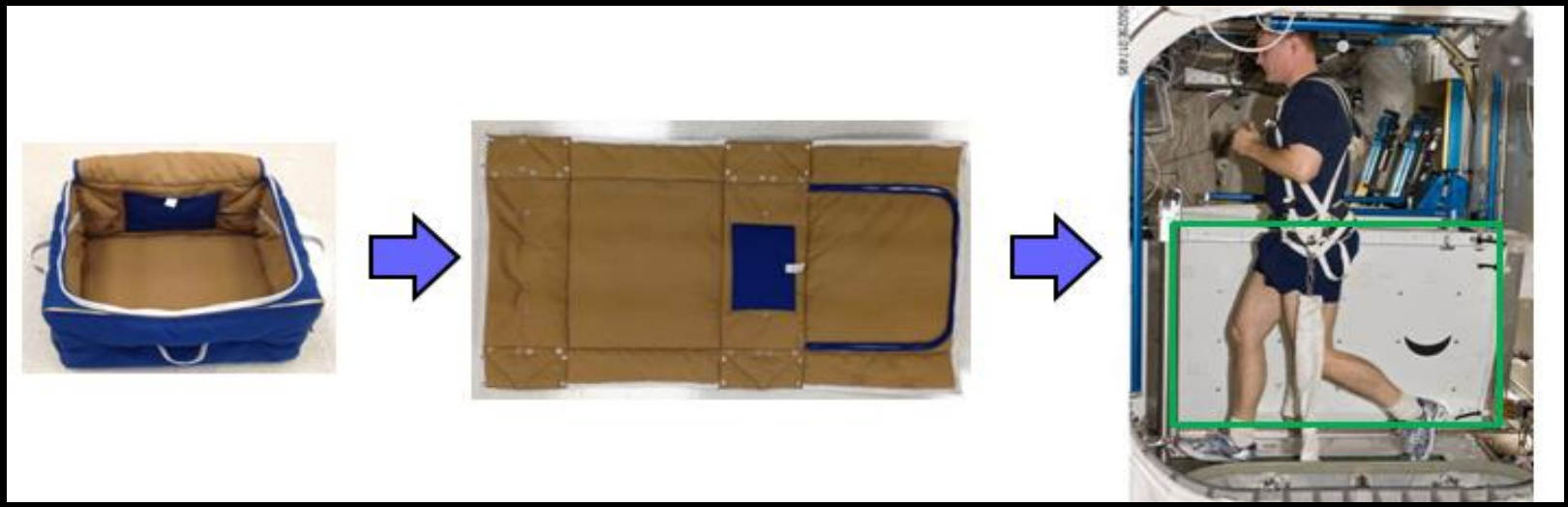
IVA CASE STUDY – CREW QUARTER

- Crew Quarter / Sleep Station
  - Custom sleeping bag
  - Teflon fabric lined interior for ease of cleaning and maintenance

IVA CASE STUDY - AMCTB

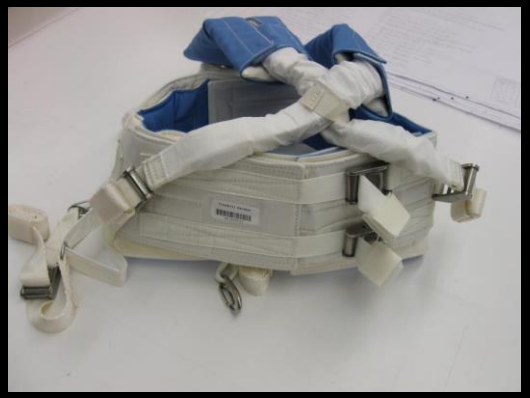
- Acoustic Multipurpose Cargo Transfer Bag (AMCTB)
  - Multi-use concept technology demonstration
  - Convertible cargo bag
  - Acoustic blanket





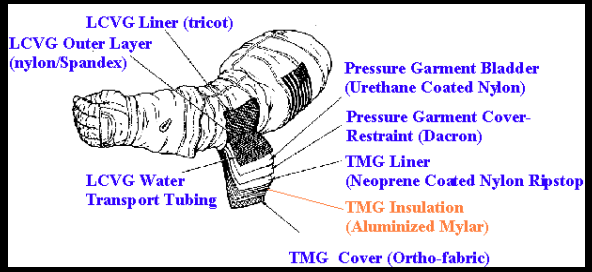
IVA CASE STUDY – TVIS HARDNESS

- Treadmill with Vibration Isolation and Stabilization (TVIS) Harness
  - Nomex webbing
  - Cotton comfort liner
  - Nomex fabric outer layer
  - Teflon fabric cover



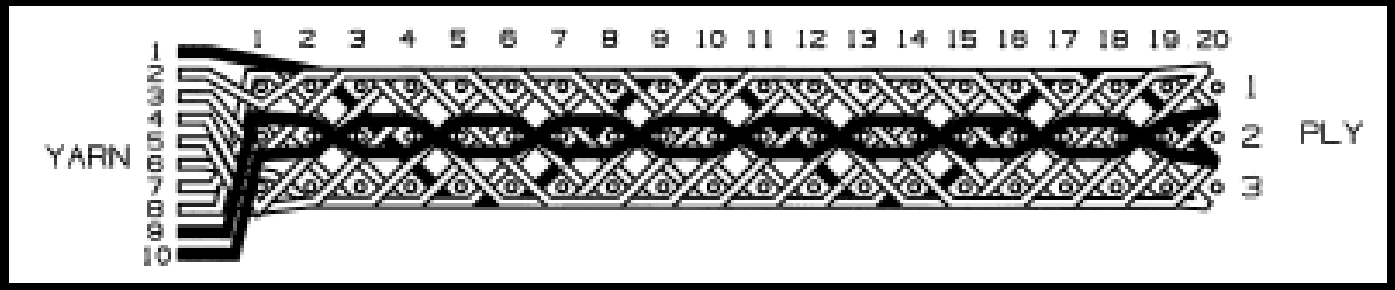
CASE STUDY – SPACESUIT

- Extravehicular Mobility Unit (EMU)
  - Thermal Micrometeor Garmet (TMG)
    - Outer layer – Ortho, Teflon / Nomex / Kevlar ripstop fabric
    - Muliti Layer Insulation – aluminum Mylar with polyester scrim
    - Restraint layer – Dacon fabric
    - Micrometeror layer – Neoprene coated nylon
  - Bladder layer – polyurethane coated nylon
  - Liquid cooling garment (LCG) – polyester fabric with EVA tubing



CASE STUDY – EVA TETHER

- EVA Tether Functions
  - Safety tether
  - Translation anchoring
  - Secure tools and requirement
- Common cord/webbing materials
  - Nomex
  - Fiberglass
  - Vectran
- Unique glass webbing construction for AO resistance

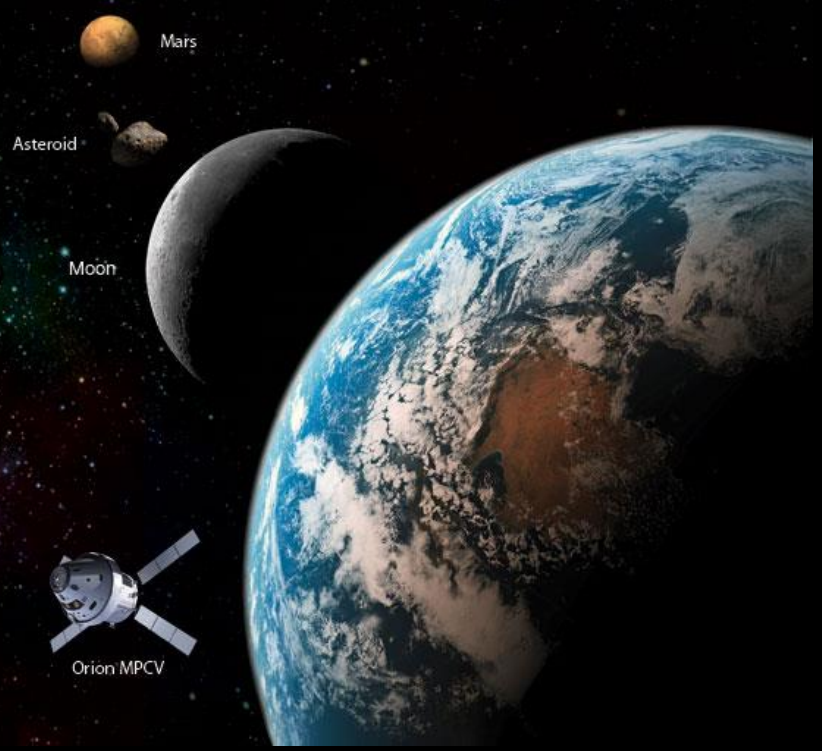


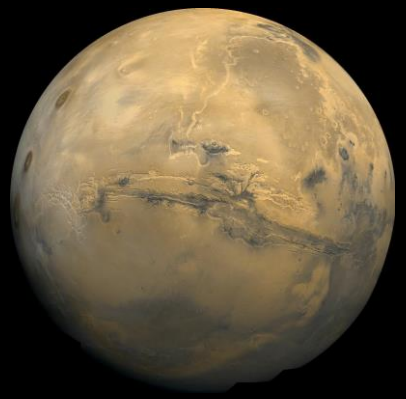
CASE STUDY – BEAM

- Bigelow Expandable Activity Module (BEAM)
  - Inflatable habitat technology demonstration (2016)
  - 565 ft^3 of habitable volume
  - Multi-layer fabric construction
    - Fabric & webbing restraint
    - Thermal and MMOD protection
    - Bladder system

BEYOND ISS– LONG DURATION MISSION

- Nonflammable textile fabric for enrich oxygen environment up to 35 % O_2
- Lightweight quick drying fabric for exercise clothing
- Nonflammable acoustic insulation nonwoven materials
- Dust resistance spacesuit outer layer fabric for Mars exploration





QUESTIONS & COMMENTS

IFAI EXPO

NASA

BACKUP

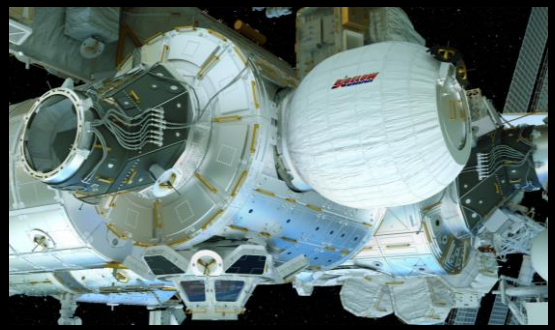
TEXTILES FOR LIVING IN SPACE

Henry Tang

NASA Johnson Space Center / Aerodyne Industries

IFAI EXPO 2017, New Orleans, LA, USA

VIDEO LINKS



BEAM Deportment

Running in Space

Living in Space